10/049732
Rec'd PCT/PTO 15 FEB 2002

Translation of PCT/EP00/08085

7/prts

Axial piston drive with a continuously adjustable piston stroke

Insert A1

State of the art

The invention relates to an axial piston drive with a continuously adjustable piston stroke according to the characterizing clause of Claim 1.

Insert A2

The use of axial piston drive with a continuously adjustable piston stroke is known in particular for motor-vehicle air conditioners, where they serve as coolant condensers.

The main components of an air conditioner for a motor vehicle are a coolant condenser, a first heat exchanger, a so-called evaporator, a second heat exchanger, a so-called liquefier or gas cooler in the case of supracritical processes, an expansion organ and conduits that connect the components to one another. The role of the coolant condenser is to suck a coolant in from the evaporator, in which the coolant evaporates at a low pressure level under heat absorption, and to condense it at a higher pressure level. Subsequently, in the second heat exchanger, the coolant release the heat at a higher pressure and temperature level, and in the expansion organ it is returned to a pressure level corresponding to that of the evaporator. The result is a closed cyclic process.

Sub A3

The output of the coolant condenser can be continuously adjusted by way of the speed of a drive motor and in an especially energetically favourable manner, in the case of axial piston drive, by way of the piston stroke. Known axial

piston drive or axial piston condensers for vehicle air conditioners comprise a drive shaft operated by way of a pulley. Within a crank chamber a swash plate is supported on the drive shaft so that it is unrotably fixed and can be tilted by way of a joint. The swash plate drives at least one piston that can move within a cylinder. In order to absorb tractive and pressure loads, each such piston is connected to the swash plate by way of two hinge yoke, one at the bearing surface of the swash plate that faces the piston and the other at the surface that faces away. With their flat surfaces contacting the bearing surfaces of the swash plate, the hinge yoke run at full circumferential velocity with a superimposed radial movement, which results in an elliptical track. The hinge yoke are seated with their rounded surfaces in sphere shaped formed bearings of the pistons, within which there is comparatively little relative movement during operation.

Furthermore, the connection between the the swash plate and the piston can be formed not only by the above hinge yoke but in addition by way of a wobble plate. The wobble plate is secured against torsion with respect to the drive shaft by either a housing or piston rods. A bearing between the swash plate and the wobble plate absorbs the entire relative movement. The wobble plate performs only a wobbling movement as a result of the rotation of the swash plate.

The piston stroke and hence the output of the axial piston drive unit is adjusted by altering the tilt angle of the swash plate. A large tilt angle results in a long piston stroke and high output, whereas with a small tilt angle the piston stroke is shorter and the output lower. As a rule, the tilt angle of the swash plate is limited to a minimal and a maximal value by two stops. Ordinarily one or two guide pins are needed to guide the tilting movement in a specified manner and to avoid jamming. The tilt limiters, i.e. the stops, can be integrated into the guide pins.

If the adjustment of the tilt angle from a maximal value to a smaller one shifts a top-dead-centre point of the piston within the cylinder in the direction of the swash plate, already compressed gas cannot be completely expelled. The compression energy introduced into the gas cannot be utilized for the cooling process. The result is a "damage space" between the piston and a valve plate on the cylinder, which causes a loss of energy. In order to avoid the "damage space" and to preserve the top-dead-centre point of the piston, the swash plate is mounted so that it can additionally be axially displaced against a prestressed compression spring. The movement of the swash plate in the axial direction is usually limited by stopping devices.

Advantages of the invention

The axial piston drive in accordance with the invention comprises a drive shaft and a radial bearing seat for a swash plate that is oriented at a first tilt angle with respect to the longitudinal direction of the shaft. Mounted on the bearing seat is a swash plate within a crank chamber, with a bore of bearing that is tilted at a second angle with respect to the perpendicular line of the swash plate. The driving action of the swash plate is exerted by connection to at least one piston that can move within a cylinder. In order to permit adjustment of the tilt angle, and hence of the piston stroke and the output, the swash plate can be rotated on the bearing seat through a certain range of angles, by means of a controller.

It is proposed that onto the rotational movement from a maximal resulting tilt angle to a minimal resulting tilt angle there should be superimposed by an axial stroke movement of the swash plate in the direction towards the piston, and moves from the minimal resulting tilt angle to the maximal resulting tilt angle, it should superimposed by an axial stroke movement in the direction away from the piston. The moments of tilt acting on the swash plate can advantageously be supported by large

bearing surfaces on the drive shaft. Jamming is avoided and a long working life of the axial piston drive can be achieved. Furthermore, the axial stroke movement enables a damage space caused by the tilting movement to be avoided or minimized. The top-dead-centre point of the piston within the cylinder can be maintained, losses can be avoided and the axial piston drive can in particular be advantageously employed as a condenser in air conditioners. The condenser can be designed as a pure swash-plate condenser or as a wobble-plate condenser. Furthermore, the solution in accordance with the invention can be applied to gear mechanisms, hydraulic pumps and so on.

The axial stroke movement can be obtained by various methods that seem suitable to a person skilled in the art, for example by way of an axially moving piston or the like. It is particularly advantageous, however, to connect the swash plate to the drive shaft by means of a screw thread, which generates the additional axial stroke movement from the rotational movement of the swash plate. With little effort, by choosing a suitable screw pitch, a desired relationship between the rotational movement and the axial stroke movement can be produced. The screw pitch is advantageously made such that for a 180° angle of rotation the swash plate is shifted axially by half of a maximal piston stroke. The top-dead-centre point of the piston stays at the same position along the cylinder track and a damage space and energy losses are avoided.

Furthermore, the swash plate can be made especially insensitive to vibrations and impacts in both axial and radial directions, as well as to torque fluctuations, by an inhibition of the thread. The thread is preferably set into radial surfaces but can also be set into axial surfaces, for instance in the form of a ring wedge and a ring-wedge counterpart, etc. The thread can also be single or multiple. With a multiple-thread screw it can advantageously be ensured that despite a steep pitch, the swash plate at both minimal and maximal tilt angle is securely connected by the thread at the drive shaft at more than one

place around the circumference. The thread can also be set into an extra component attached to the drive shaft, for example an oblique cylinder. In one embodiment it is proposed that the thread be integrally formed in the drive shaft, for a saving in the number of additional components and the effort and expense of assembly. To enable an especially simple assembly and so that during the shifting process the centre of mass of the shifted parts can be displaced along a desired axis, in particular along the shaft axis, the swash plate is advantageously rotatably mounted on an axially displacable sleeve.

The controller comprises at least one adjustment unit, by means of which an adjustment force can be applied to tilt and axially displace the swash plate. The adjustment unit can be formed in part by the piston, in that by variation of a gas-pressure difference between the upper side of the piston and the lower side of the piston in the crank chamber an adjustment force is generated that shifts the swash plate against a counterforce device. The counterforce device can be formed by a compression spring or, advantageously, by a torsion spring that exerts a torque directly on the swash plate and hence can be incorporated more easily and perhaps more economically than a compression spring.

Furthermore, it is possible for the controller to comprise an adjustment unit separate from the piston, to shift the swash plate. With an adjustment unit that is separate from the piston the size of the range of control can be independent of the operating points. Flow losses between the upper side of the piston and the crank chamber can be reduced. Moreover, the axial piston drive can be operated with low pressure in the crank chamber. A leakage flow of coolant from the crank chamber and outwards through shaft seals is approximately proportional to the pressure in the crank chamber. With a slight pressure an elaborate sealing of the crank chamber can be eliminated and the leakage flow made smaller. This is advantageous in

particular in the case of coolants with high absolute pressures, for which in general high pressures in the crank chamber are needed to achieve control by way of a gas-pressure difference at the piston. With a low pressure, furthermore, the coolant of an air conditioner is only slightly soluble in a lubricant of the condenser, as a result of which a high viscosity can be maintained.

Another way in which a separate adjustment unit has a positive effect on viscosity is that heating of the lubricant by gas that has been warmed by the high-pressure side of the piston can be avoided. With a high viscosity, low friction between heavily loaded pairs of sliding elements on the swash plate and between the pistons and the cylinders can be achieved, which contributes to a long working life and a high degree of reliability.

With an adjustment unit separate from the piston, no particular pressure in the crank chamber is needed for control, as a result of which coolant can be conducted from an evaporator through the crank chamber into the cylinder. Therefore the crank chamber can be cooled, an additional suction chamber on the upper side of the piston can be avoided, and hence the whole structure occupies less space. Furthermore, it is usually possible to utilize a large volume of the crank chamber for the attenuation of gas pulsations.

The adjustment unit can be driven by electrical, pneumatic or preferably hydraulic means. With hydraulic fluid an advantageous damping of oscillation can be achieved and a particularly vibration-insensitive axial piston drive created. The adjustment unit can act directly on the swash plate, with a torque and/or with an axial adjustment force. An adjustment unit with an axial action can be particularly easily sealed off and economically constructed. In the case of an adjustment unit that exerts a torque on the swash plate, the controlling torque acts directly in the direction of the rotational movement of

the swash plate, as a result of which the swash plate can be tilted and axially displaced with a small controlling torgue and a small, space-saving adjustment unit.

The hydraulic adjustment unit can be supplied with compressed oil by a hydraulic unit that is independent of the medium being propelled by the piston; for example, a hydraulic unit that is already present in a motor vehicle can advantageously be used for this purpose. Additional components can then be eliminated and a large range of control, independent of the operating points of the axial piston drive, can be attained. Furthermore, no build-up of pressure is needed for control when the axial piston drive is started up, for instance through a minimal tilt angle of 2°. A load-free starting of the axial piston drive is made possible, and it becomes easier to start for instance an internal combustion engine that powers the axial piston drive.

With an oil trap connected downstream of the condenser, on the high-pressure side, good heat transfer into the heat exchanger can be ensured and a high efficiency of an air conditioner achieved. Furthermore, the oil trap can be put to particularly good use if it supplies the hydraulic adjustment unit with pressurized oil. Pressure is applied to the oil from the oil trap depending on the operating point. If a large moment of displacement is required, the pressure in the oil trap is high; if only a small moment of displacement is needed, the pressure there is low.

In one embodiment it is proposed to connect the hydraulic adjustment unit to the crank chamber by way of a drain, which is a particularly useful arrangement in that the oil trap and the adjustment unit can be used to transport the lubricant back into the crank chamber. In this process, a flow from the oil trap to the adjustment unit and/or the drain from the adjustment unit to the crank chamber can be made controllable. The uncontrolled part is advantageously formed by a throttling site.

Drawing

Additional advantages will be apparent from the following description of drawings, which show exemplary embodiments of the invention. The drawings, the description and the claims contain numerous characteristics in combination. A person skilled in the art will be able also to consider the characteristics individually and to assemble them into other useful combinations.

The individual figures show the following:

Fig. 1 an axial piston drive with the piston at the maximal end of its stroke, in section;

Fig. 2 a section along the line II-II in Fig. 1;

Fig. 3 an axial piston drive according to Fig. 1 with the piston at the minimal end of its stroke, in section;

Fig. 4 a section along the line IV-IV in Fig. 3;

Fig. 5 an axial piston drive with a hydraulic adjustment unit;

Fig. 6 a section along the line VI-VI in Fig. 5;

Fig. 7 a schematic diagram of a form of hydraulic control, and

Fig. 8 part of a variant according to Fig. 2.

Description of the exemplary embodiments

Fig. 1 shows an axial piston drive for an air conditioner of a motor vehicle, which operates as a condenser. The axial piston

drive comprises a drive shaft 10 with bearing seat 14 for a swash plate 16, which is set at a first tilt angle 22 (Fig. 2) with respect to the longitudinal direction 20. When positioned on the bearing 14 within a crank chamber 24, the swash plate 16 is seated in a bore of bearing 30 that is tilted at a second angle 28 with respect to a perpendicular line 26 of the swash plate 16. With respect to its driving action, by way of hemispherical hinge yoke 78, 80, 82, 84, 86, 88, 90, 92 the swash plate 16 is connected to four pistons 44, 46, 48, 50 guided within cylinders 36, 38, 40, 42 (Figs. 3 and 4). To absorb tractive and pressure loads, each piston 44, 46, 48, 50 is connected to the swash plate 16 by two of the hinge yoke 78, 80, 82, 84, 86, 88, 90, 92, in such a way that one of the hinge yoke 78, 80, 82, 84, 86, 88, 90, 92 contacts the bearing surface 96 of the swash plate 16, faces towards the piston 44, 46, 48, 50, whereas the other hinge yoke contacts the bearing surface 94 of the swash plate 16, which faces away from the piston. The hinge yoke 78, 80, 82, 84, 86, 88, 90, 92 run, by way of their flat surfaces, along the bearing surfaces 94, 96 of the swash plate 16 with full circumferential velocity with superimposed radial movement, as a result of which an elliptical track is produced. The rounded surfaces of the hinge yoke 78, 80, 82, 84, 86, 88, 90, 92 are seated in sphere shaped formed bearings 98, 100, 102, 104, 106, 108, 110, 112 of the pistons 44, 46, 48, 50, within which there is comparatively little relative movement during operation.

So that the piston stroke and hence the ouput of the axial piston drive can be continuously adjusted, the swash plate 16 is made so that it can be rotated on the bearing seat 14 within a certain range of angles by means of a controller 32. When the bearing seat 14 and the bore of bearing 30 are tilted in the same direction, the tilt angles 22, 28 add up to a maximal resulting tilt angle 52 (Fig. 2); if the bearing seat 14 and the bore of bearing 30 are tilted in opposite directions, the tilt angles 22, 28 are subtracted, resulting in a minimal tilt angle 54 (Fig. 4). The minimal resulting tilt angle 54 amounts

Sub B1

to ca. 2°, so as to ensure that pressure will be built up when the axial piston drive is started.

In accordance with the invention, onto the rotational movement from the maximal resulting tilt angle 52 to the minimal resulting tilt angle 54 there is superimposed an axial stroke movement 56 of the swash plate 16 in the direction towards the pistons 44, 46, 48, 50, whereas onto the rotational movement from the minimal resulting tilt angle 54 to the maximal resulting tilt angle 52 there is superimposed an axial stroke movement 116 of the swash plate 16 in the direction away from the pistons 44, 46, 48, 50 (Figs. 1-4). The swash plate 16 is connected to the drive shaft 10 by a thread 58, which generates the supplementary stroke movement 56, 116 from the rotational movement of the swash plate 16. The thread 58 is integrally formed on the drive shaft 10 and its pitch is such that when the swash plate 16 rotates through 180°, it is displaced axially by a distance equal to half of a maximal piston stroke 60 and a top-dead-centre point 114 of the pistons 44, 46, 48, 50 remains at the same place within the cylinder track (Figs. 2 and 4). The stroke movement 56, 116 and the rotational movement of the swash plate 16 are limited by stops 120, 122 attached to the drive shaft 10, by which the drive shaft is supported 10 in the axial direction against a lid 162 and a housing 164 of the axial piston drive by way of thrust bearings 160 and thrust washers 168. Radially, the drive shaft 10 is seated by way of two radial bearings 166 in the cover 162 and in the housing 164.

The controller 32 comprises an adjustment unit formed in part by the pistons 44, 46, 48, 50. By variation of a gas-pressure difference between the upper side 118 of the pistons 44, 46, 48, 50 and the lower side of the pistons 44, 46, 48, 50 in the crank chamber 24, with channels and control valves not shown in detail here, an adjustment force is produced (Fig. 1) that displaces the swash plate 16 against a counterforce mechanism. The counterforce mechanism is formed by four pretensioned

torsion springs 62, 64, 66, 68. The torsion springs 62, 64, 66, 68 are supported against the stop plates 120, 122 of the swash plate 16 and act on the swash plate 16 by way of stops not shown in detail here. When the swash plate 16 is shifted from the maximal resulting tilt angle 52 to the minimal resulting tilt angle 54, the prestress of the torsion springs 62, 64, 66, 68 is increased. When the swash plate 16 is shifted from the minimal resulting tilt angle 54 to the maximal resulting tilt angle 52, the prestress of the torsion springs 62, 64, 66, 68 is reduced. Between the maximal and minimal resulting tilt angles 52, 54 the swash plate 16 can be continuously adjusted to any desired tilt angles. The swash plate 16 is displaced along a tilted central axis, as a result of which the swash plate is slightly eccentric when in the extreme positions. An umbalance in the extreme positions can advantageously be avoided by providing compensatory masses.

Fig. 8 shows part of a variant according to Fig. 1 with a drive shaft 170. On the drive shaft 170 a sleeve 178 is disposed so as to be axially displaceable and rotationally fixed. The sleeve 178 comprises a bearing seat 14 on which a swash plate 174 with a bearing hole 30 is rotatably mounted. The swash plate 174 is supported axially and radially on the sleeve 178 by way of antifriction bearings 182, 184, 186 and is coupled by way of a coupling 176 to a nut 180 that is connected to the drive shaft 170 by a screw thread 172. Regarding the adjustment function, the essential aspects will be evident from the description of the exemplary embodiment in Figs. 1 to 4. The major difference is that the swash plate 174 can be installed especially simply and, in addition, by appropriately configuring the sleeve 178 the centre of mass of the parts that are to be displaced can be guided along the axis of the shaft.

Figure 5 shows an axial piston drive with a controller 34 that comprises a hydraulic adjustment unit 70 separate from the pistons 44, 46, 48, 50. In the exemplary embodiments shown here, components that are substantially the same are

fundamentally identified by the same reference numerals. The adjustment unit 70 comprises a wheel with two vanes 128, 130 126 supported in a housing 124 (Fig. 6) which, in combination with two vanes 132, 134 on the housing 124, form four chambers 136, 138, 140, 142. In order to rotate a swash plate 18 on a drive shaft 12, the two chambers 142, 138 receive high oil pressure through an axial and a radial borehole 144, 146 in the drive shaft 12 and through a radial borehole 148 in the wheel 126. The wheel 126 is attached to the drive shaft 12, whereas the housing 124 can be rotated with respect to the wheel 126, exerts a torque on the swash plate 18 by way of a joining element 150, and displaces the swash plate 18 against the force exerted by the prestressed torsion springs 66, 68. The joining element 150 engages a recess 152 in the swash plate 18, can be shifted in the axial direction relative to the swash plate 18, and is in contact with the swash plate 18 over the entire range of displacement.

The adjustment unit 70 is provided through an influx 76 with compressed oil by an oil separator 72 disposed downstream of the cylinders 36, 38, 40, 42 and the adjustment unit 70 is connected to the crank chamber 24 by a drain 74 (Fig. 7). The coolant that has been separated from the oil is sent from the oil separator 72 to a low-pressure side of the air conditioning unit, as indicated by the arrow 154. The influx 76 running from the oil separator 72 to the adjustment unit 70 and the drain 74 from the adjustment unit 70, which runs to the crank chamber 24, are each controllable by a valve 156, 158. Furthermore, it would be possible to replace a valve 156 or 158 by a fixed throttling site.

List of reference numerals

10	Drive shaft
12	Drive shaft
14	Bearing seat
16	Swash plate
18	Swash plate
20	Longitudinal direction
22	Tilt angle
24	Crank chamber
26	Perpendicular line
28	Tilt angle
30	Bore of bearing
32	Controller
34	Controller
36	Cylinder
38	Cylinder
40	Cylinder
42	Cylinder
44	Piston
46	Piston
48	Piston
50	Piston
52	Tilt angle
54	Tilt angle
56	Stroke movement
58	Thread
60	Piston stroke
62	Torsion spring
64	Torsion spring
66	Torsion spring
68	Torsion spring
70	Adjustment unit
72	Oil separator
74	Drain
76	Influx
78	Hinge yoke
80	Hinge yoke
82	Hinge yoke
84	Hinge yoke
86	Hinge yoke
88	Hinge yoke
90	Hinge yoke
92	Hinge yoke
94	Bearing surface
96	Bearing surface
98	Bearing
100	Bearing
102	Bearing
104	Bearing
106	Bearing
108	Bearing
110	Bearing
112	Bearing
114	Top dead centre
116	Stroke movement
118	Upper side
120	Stop
122	Stop
124	Housing
126	Wheel
128	Vane
130	Vane
132	Vane
134	Vane
136	Chamber
138	Chamber
140	Chamber
142	Chamber
144	Borehole

146 Borehole
148 Borehole
150 Joining element
152 Recess
154 Arrow
156 Valve
158 Valve
160 Thrust bearing
162 Lid
164 Housing
166 Bearing
168 Thrust washers
170 Drive shaft
172 Thread
174 Swash plate
176 Coupling
178 Sleeve
180 Nut
182 Antifriction bearing
184 Antifriction bearing
186 Antifriction bearing